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SHORT COMMUNICATION

Relation between sugar-sweetened beverage consumption and micronutrient intake in a prospective study

P Mullie[1,2,3], E Mertens[1,4], R Charlier[4], SS Knaeps[4,5], J Lefevre[4] and P Clarys[2,3]

Micronutrient dilution following sugar-sweetened beverage (SSB) consumption can lead to a qualitative impoverishment of a dietary pattern. The aim of this prospective study was to investigate the relation between SSB consumption and micronutrients. A total 562 adults were tested in 2002 and 2012 for the same anthropometric, lifestyle and nutritional intake activity parameters. Calcium, iron and magnesium intake decreased with increasing baseline SSB intake, and with increasing SSB consumption during the 10 years. A 100 ml increase in SSB consumption was associated with a 22 mg lower intake of calcium, 0.4 mg of iron and 9 mg of magnesium. There was no relation between vitamins and SSB consumption. In conclusion, there was limited evidence in our study, which suggests SSB have minimal dilutional effect on dietary micronutrient consumption. A major limitation of the present study is that of the original 1569 participants in 2002, 36% returned for participation in 2012.

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INTRODUCTION

It has been hypothesized that an increased sugar-sweetened beverage (SSB) consumption in a dietary pattern could create an imbalance in micronutrient intake, because the micronutrient density of SSB is lower than the micronutrient density usually found in natural sugar-containing foods, that is, fruits. This micronutrient dilution, that is, a lower intake of micronutrients for equal energy consumption, could lead to a qualitative impoverishment of a dietary pattern.[1–3]

Three major reviews related added sugar, a major component of SSB, to micronutrient dilution.[1–3] These reviews concluded that the existing evidence of an inverse relation between reported intakes of added sugar and micronutrients was inconsistent. According to Rennie *et al*. and Livingstone *et al*.,[1–3] there were insufficient data and inconsistency between the studies relating added sugars and micronutrient intakes, with no clear evidence of micronutrient dilution. Gibson *et al*.[3] concluded that the available evidence did not allow for firm conclusions on an optimal level of added sugar intake for micronutrient adequacy while the inversed trends that exist may have little biological significance.

The aim of the present study was to investigate the influence of time changes in SSB consumption on the intake of micronutrients in a prospective study. We limited our analysis to vitamins and minerals with suboptimal intake in the Belgian population.[4]

MATERIALS AND METHODS

Data were collected by the Flemish Policy Research Centre Sport, Physical Activity and Health.[5] One of the aims of this Research Centre was to investigate the relationship between nutritional habits, physical health, mental health and physical fitness among an adult population. The first test moment took place during 2002, the second test moment during 2012. Of the original 1569 participants, 367 men and 195 women returned for participation. The subjects were asked to visit the test laboratory to have anthropometric measurements taken and to complete questionnaires. All the participants signed an informed consent form and received information about the tests and measurements. The study was approved by the ethical and medical committee of the Catholic University of Leuven, Belgium.

The participants completed a 3-day food record. Diet records were analysed using Becel Nutrition software (Unilever Co., Rotterdam, The Netherlands). SSB consumption was defined as the consumption of beverages with added sugar, such as soft drinks; fruit juice and artificially sweetened beverage consumption were excluded. The use of dietary supplements was not assessed.

SPSS 22.0 (SPSS Inc., Chicago, IL, USA) statistics software was used for data analysis. Chi-square tests and paired samples *T*-tests were used for characterization of the participants and to compare body mass index (BMI) between the two test moments. Residual change scores for SSB and total energy intake were created by regressing the follow-up measures onto their respective baseline measures. The residualized change scores can be interpreted as the amount of change between the first and second test moment, independent of baseline levels and are preferable to simple change scores because they eliminate auto-correlated error and regression to the mean effects. The SSB consumption had a non-normal distribution, with a high number of non-consumers. To correct this, the logarithm was used in the multivariate models. Energy intake was expressed in 40 kcal units, which is equal to 10 g of sugar or 100 ml SSB, allowing interpretation of the regression models. Associations between micronutrients were tested in a multivariate linear regression with the 2012 micronutrient intake as continuous dependent variable, and baseline values for minerals, age, gender, energy intake, baseline log SSB, SSB residuals, energy residuals as independent variables. A two-sided 0.05 level of significance was defined.

RESULTS

Exposure and outcomes were assessed in 2002 and 2012 in 562 middle-aged adults (367 men and 195 women; Table 1).

[1]International Prevention Research Institute, Lyon, France; [2]Faculty of Physical Education and Physiotherapy, Movement and Sport Sciences, Department of Human Biometrics and Biomechanics, Vrije Universiteit Brussel, Brussels, Belgium; [3]Erasmus University College, Department of Health Care, KC Brussels Integrated Care, Brussels, Belgium; [4]Faculty of Kinesiology and Rehabilitation Sciences, Department of Kinesiology, KU Leuven, Leuven, Belgium and [5]Department of Movement and Sports Sciences, Ghent University, Ghent, Belgium. Correspondence: Professor PP Mullie, Faculty of Physical Education and Physiotherapy, Movement and Sport Sciences, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussels, Belgium.
E-mail: patrick.mullie@skynet.be
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Table 1. Description of the participants to the test periods 2002 and 2012

	2002				2012			
	Males		Females		Males		Females	
	n	%	n	%	n	%	n	%
BMI below 25.0 kg/m^2	173[a]	47.1	136[a]	69.7	157[a]	42.8	131[a]	67.2
BMI between 25.0 and 29.9 kg/m^2	177	48.2	50	25.6	178	48.5	53	27.2
BMI more than 30.0 kg/m^2	17	4.6	9	4.6	32	8.7	11	5.6
Total	367		195		367		195	
	Mean	*s.d.*	*Mean*	*s.d.*	*Mean*	*s.d.*	*Mean*	*s.d.*
Age	46.9	8.4	45.3	8.4	57.4	10.2	55.8	8.4
BMI (kg/m^2)	25.4[a]	2.7	23.4[a]	3.0	25.7[a]	3.0	24.1[a]	3.4
Total energy (kcal)	2590[a]	675	2026	499	2421[a]	626	1958	542
Total energy (kJ)	10 848[a]	2825	8482	2089	10 139[a]	2623	8200	2270
Proteins (g)	98.2[a]	25.7	79.9	22.0	93.3[a]	25.2	77.0	18.6
Proteins (en-%)	15.5	3.3	16.0	3.3	15.8	3.7	16.2	3.6
Carbohydrates (g)	296.5[a]	89.8	228.3	64.6	272.1[a]	82.8	218.5	69.2
Carbohydrates (en-%)	45.9	7.5	45.2	6.7	45.0	7.8	44.7	7.4
Total sugar (g)	88[a]	45	69	35	80[a]	42	64	35
Total sugar (en-%)	13.5	5.9	13.7	5.6	13.1	5.7	13.0	5.8
Total fat (g)	100.0[a]	37.4	80.3	29.1	93.5[a]	35.6	78.8	30.3
Total fat (en-%)	34.2	7.0	35.2	7.0	34.2	6.9	35.5	6.9
Sugar-sweetened beverages (ml)	129	240	51	151	83	198	31	154
Calcium (mg)	909[a]	400	863[a]	371.0	873[a]	336	820[a]	293
Iron (mg)	14.3[a]	4.4	11.6	3.1	14.1[a]	4.7	12.4	5.2
Magnesium (mg)	368[a]	105	303[a]	81	362[a]	99	317[a]	81.0
Sodium (mg)	3630[a]	1082	2770	884.3	3377[a]	1044	2844	1450
Ascorbic acid (mg)	107[a]	85	118[a]	88	106[a]	83	118[a]	94
Cholecalciferol (μg)	2.1[a]	1.6	1.7	1.8	1.8[a]	1.3	1.6	1.6
Folic acid (μg)	0.8	5.1	1.1[a]	6.7	0.5	6.1	0.4[a]	3.1
Thiamine (mg)	1.5[a]	0.5	1.2[a]	0.4	1.4[a]	0.4	1.2[a]	0.4
Tocopherols (mg)	7.8[a]	7.7	5.7[a]	5.7	7.6[a]	7.9	6.6[a]	6.7

Abbreviations: BMI, body mass index; en-%, energy-percent. [a]$P < 0.05$ according to chi-square test or paired *t*-test.

Table 2. Linear regressions with minerals and vitamins at end point as dependent variables, and baseline values for minerals, age, gender, energy intake, log SSB, SSB residuals, energy residuals as independent variables

Dependent variables	*Independent variables*	*Linear regression analysis β-coefficients*	*Standard error*	*95% CI—lower bound*	*95% CI—higher bound*	P-*value*
Calcium (mg) 2012	Constant	750.278	71.942	608.965	891.592	< 0.001
	Gender (male vs female)	7.555	27.530	− 46.522	61.631	0.011
	Age 2002	− 3.034	1.255	− 5.499	− 0.569	0.016
	Calcium (mg) 2002	0.279	0.034	0.213	0.345	< 0.001
	Log SSB 2002 (ml/day)	− 20.905	11.222	− 42.947	1.137	0.063
	SSB residuals (ml/day)	− 0.220	0.078	− 0.373	− 0.066	0.005
	Energy 2002 (unit 40 kcal)	0.115	0.850	− 1.555	1.785	0.892
	Energy residuals (unit 40 kcal)	9.776	0.865	8.077	11.475	< 0.001
			$R^2 = 0.28$, F (7554) = 31.33, $P < 0.001$			
Iron (mg) 2012	Constant	10.263	1.046	8.210	12.317	< 0.001
	Gender (male vs female)	0.204	0.405	− 591.000	0.999	0.615
	Age 2002	− 0.006	0.018	− 0.042	0.030	0.752
	Iron (mg) 2002	0.204	0.054	0.097	0.311	< 0.001
	Log SSB 2002 (ml/day)	− 0.419	0.164	− 0.742	− 0.097	0.011
	SSB residuals (ml/day)	− 0.004	0.001	− 0.006	− 0.002	0.001
	Energy 2002 (unit 40 kcal)	0.017	0.014	− 0.011	0.044	0.243
	Energy residuals (unit 40 kcal)	0.195	0.013	0.170	0.220	< 0.001
			$R^2 = 0.28$, F (7554) = 31.33, $P < 0.001$			
Magnesium (mg) 2012	Constant	245.198	17.380	211.059	279.337	< 0.001
	Gender (male vs female)	6.042	6.679	− 7.077	19.161	0.366
	Age 2002	− 0.648	0.303	− 1.243	− 0.053	0.033
	Magnesium (mg) 2002	0.394	0.037	0.321	0.467	< 0.001
	Log SSB 2002 (ml/day)	− 9.869	2.767	− 15.303	− 4.434	< 0.001

Table 2. (Continued)

Dependent variables	Independent variables	Linear regression analysis β-coefficients	Standard error	95% CI—lower bound	95% CI—higher bound	P-value
	SSB residuals (ml/d)	−0.093	0.019	−0.130	0.056	< 0.001
	Energy 2002 (unit 40 kcal)	−0.022	0.233	−0.480	0.435	0.923
	Energy residuals (unit 40 kcal)	4.072	0.209	3.662	4.482	< 0.001
			$R^2 = 0.52$, F (7554) = 86.58, $P < 0.001$			
Sodium (mg) 2012	Constant	1453.912	349.153	768.085	2139.738	< 0.001
	Gender (male vs female)	−88.821	136.433	−356.811	179.169	0.515
	Age 2002	2.656	6.143	−9.409	14.722	0.666
	Sodium (mg) 2002	0.369	0.074	0.223	0.514	< 0.001
	Log SSB 2002 (ml/day)	60.260	54.614	−47.016	167.536	0.270
	SSB residuals (ml/day)	−0.208	0.383	−0.961	0.545	0.588
	Energy 2002 (unit 40 kcal)	6.644	4.925	−3.029	16.318	0.178
	Energy residuals (unit 40 kcal)	35.910	4.240	27.581	44.239	< 0.001
			$R^2 = 0.21$, F (7554) = 21.28, $P < 0.001$			
Ascorbic acid (mg) 2012	Constant	23.897	20.665	−16.693	64.488	0.248
	Gender (male vs female)	−21.285	8.053	−37.103	−5.467	0.008
	Age 2002	0.778	0.365	0.061	1.495	0.033
	Ascorbic acid (mg) 2002	0.342	0.040	0.263	0.420	< 0.001
	Log SSB 2002 (ml/day)	1.961	3.237	−4.398	8.320	0.545
	SSB residuals (ml/day)	−0.013	0.023	−0.058	0.032	0.569
	Energy 2002 (unit 40 kcal)	0.415	0.226	−0.029	0.858	0.067
	Energy residuals (unit 40 kcal)	1.082	0.252	0.587	1.577	< 0.001
			$R^2 = 0.16$, F (7554) = 15.45, $P < 0.001$			
Cholecalciferol (μg) 2012	Constant	0.877	0.342	0.205	1.549	0.011
	Gender (male vs female)	−0.045	0.133	−0.307	0.216	0.733
	Age 2002	0.005	0.006	−0.007	0.017	0.394
	Cholecalciferol (μg) 2002	0.139	0.035	0.071	0.207	< 0.001
	Log SSB 2002 (ml/day)	−0.058	0.054	−0.164	0.047	0.279
	SSB residuals (ml/day)	−0.001	0.001	−0.001	0.001	0.182
	Energy 2002 (unit 40 kcal)	0.007	0.004	0.001	0.015	0.067
	Energy residuals (unit 40 kcal)	0.028	0.004	0.020	0.037	< 0.001
			$R^2 = 0.12$, F (7554) = 10.73, $P < 0.001$			
Folic acid (μg) 2012	Constant	0.446	0.544	−0.623	1.515	0.413
	Gender (male vs female)	−0.142	0.213	−0.559	0.276	0.506
	Age 2002	0.001	0.010	−0.018	0.020	0.886
	Folic acid (μg) 2002	0.069	0.010	0.050	0.089	< 0.001
	Log SSB 2002 (ml/day)	0.090	0.086	−0.078	0.258	0.295
	SSB residuals (ml/day)	0.001	0.001	−0.010	0.001	0.758
	Energy 2002 (unit 40 kcal)	−0.006	0.006	−0.017	0.006	0.340
	Energy residuals (unit 40 kcal)	0.001	0.007	−0.012	0.015	0.829
			$R^2 = 0.08$, F (7554) = 7.289, $P < 0.001$			
Thiamine (mg) 2012	Constant	0.732	0.088	0.559	0.904	< 0.001
	Gender (male vs female)	0.036	0.034	−0.031	0.102	0.294
	Age 2002	0.004	0.002	−0.003	0.003	0.977
	Thiamine 2002	0.230	0.035	0.162	0.298	< 0.001
	Log SSB 2002 (ml/day)	−0.020	0.014	−0.047	0.007	0.141
	SSB residuals (ml/day)	0.001	0.001	0.001	0.001	0.006
	Energy 2002 (unit 40 kcal)	0.005	0.001	0.002	0.007	< 0.001
	Energy residuals (unit 40 kcal)	0.018	0.001	0.016	0.020	< 0.001
			$R^2 = 0.45$, F (7554) = 63.466, $P < 0.001$			
Tocopherols (mg) 2012	Constant	4.611	1.750	1.174	8.048	0.009
	Gender (male vs female)	0.556	0.680	1.892	0.781	0.414
	Age 2002	0.002	0.031	−0.059	0.064	0.941
	Tocopherols (mg) 2002	0.394	0.042	0.311	0.477	< 0.001
	Log SSB 2002 (ml/day)	−0.127	0.274	−0.665	0.410	0.642
	SSB residuals (ml/day)	0.003	0.002	−0.001	0.007	0.148
	Energy 2002 (unit 40 kcal)	0.004	0.019	−0.034	0.042	0.837
	Energy residuals (unit 40 kcal)	0.135	0.020	0.090	0.180	< 0.001
			$R^2 = 0.20$, F (7554) = 19.78, $P < 0.001$			

Over the 10-year period, men's and women's BMI gained 0.3 and 0.7 kg/m^2 on average. Between 2002 and 2012, the mean energetic intake decreased from 2590 to 2421 kcal/day for men and from 2026 to 1958 kcal/day for women ($P < 0.01$). Mean sugar intake remained stable for men and for women, 13.5 to 13.1 energy-percent and 13.7 to 13.0 energy-percent, respectively. Mean daily intake of SSB decreased from 129 to 83 ml in men and from 51 to 31 ml in women.

Table 2 presents the results of linear regressions with mineral and vitamin intake at 2012 as dependent variables, and baseline values for minerals, age, gender, energy intake, baseline log SSB, SSB residuals and energy residuals as independent variables. Calcium, iron and magnesium intake decreased with increasing baseline SSB intake, and with increasing SSB consumption during the 10 years. There was no relation between vitamins and SSB consumption, except for thiamine.

DISCUSSION

In this prospective study, only calcium, iron and magnesium decreased with increasing SSB consumption. This was not the case for other micronutrients, providing no evidence for a general micronutrient dilution. However, the decrease in calcium, iron and magnesium was associated with higher baseline SSB consumption and with increasing SSB consumption during the observed time period.

The relation between micronutrients and SSB can be influenced by the associated dietary pattern. For example, SSB consumption has been associated with lower daily consumption of fruits and vegetables, both micronutrient rich foods.[1] This may indicate that a high SSB intake may be part of a general unhealthy behaviour, and that, when relating SSB to an outcome, it may be difficult to disentangle the specific health-related effect of SSB from other related unhealthy behaviours.

A major limitation of the present study is that of the original 1569 participants in 2002, 36% returned for participation in 2012. However, the aim of our study was not to describe a representative sample of a population.

In conclusion, in this study, there was limited evidence of micronutrient dilution. Further research should be done to determine the clinical consequences on mineral intake.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

PC and JL worked on the original idea for the study. PM analysed the data and drafted the first version of the manuscript. All the authors read and approved the final version of the review.

REFERENCES

1 Rennie KL, Livingstone MB. Associations between dietary added sugar intake and micronutrient intake: a systematic review. *Br J Nutr* 2007; **97**: 832–841.
2 Gibson SA. Dietary sugars intake and micronutrient adequacy: a systematic review of the evidence. *Nutr Res Rev* 2007; **20**: 121–131.
3 Livingstone MB, Rennie KL. Added sugars and micronutrient dilution. *Obes Rev* 2009; **10**(Suppl 1): 34–40.
4 Devriese S, Huybrechts I, Moreau M, Van Oyen H. *The Belgian Food Consumption Survey 1 - 2004*. Scientific Institute of Public Health: Brussels, Belgium, 2006.
5 Duvigneaud N, Wijndaele K, Matton L, Deriemaeker P, Philippaerts R, Lefevre J *et al.* Socio-economic and lifestyle factors associated with overweight in Flemish adult men and women. *BMC Public Health* 2007; **7**: 23.